FARADAY ROTATION FOR SMOS RETRIEVALS OF OCEAN SALINITY AND SOIL MOISTURE

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ABSTRACT

Faraday rotation is a change in polarization as radiation propagates from the surface through the ionosphere to the sensor. At L-band (1.4 GHz) this change can be significant and can be important for the remote sensing of soil moisture and ocean salinity from space. Consequently, modern L-band radiometers (SMOS, Aquarius and SMOS) are polarimetric to measure Faraday rotation "in situ" so that a correction can be made. This is done using the ratio of the third and second Stokes parameters. In the case of SMOS this procedure has produced very noisy estimates. An alternate procedure is reported here in which the total electron content is estimated and averaged to reduce noise.

1. INTRODUCTION

Faraday rotation is the change in polarization that occurs when an electromagnetic signal propagates through the ionosphere (a birefringent medium). At L-band (1.4 GHz) this change can be significant and it can be an important consideration for remote sensing of soil moisture and ocean salinity which are measured at L-band. In fact, all of the recent L-band radiometers launched in space (SMOS, Aquarius and SMAP) include polarimetric channels to estimate the rotation angle "in-situ". This can be done using the ratio of the third Stokes parameter, T3, and second Stokes parameter $Q = Tv - Th$, as proposed by Yueh [8] and demonstrated with measurements from Aquarius [4]. Figure 1 is an example using data from SMAP.

The retrieval of the Faraday rotation angle from the SMOS polarimetric channels has been difficult to verify because of the relatively noisy measurements themselves. As a result alternative approaches have been reported [1, 7]. In this manuscript an approach is reported in which noise in the retrieval is reduced by calculating and averaging the equivalent TEC (total electron content) associated with each pixel in the SMOS snap shot. The TEC is relatively slowly varying in contrast to the Faraday rotation which is strongly dependent on the orientation of the propagation path with respect to the Earth magnetic field. Noise is further reduced by including several overlapping snap shots in the average. An average value is computed for each pixel and also averaged over the entire "snap shot".

The hypothesis is that a stable estimate of Faraday rotation can be obtained for each ray path using this average value of TEC.

2. CALCULATION OF FARADAY ROTATION AND TEC

The angle of rotation, Ω_F, of the polarization vector can be computed from the ratio of the third Stokes parameter, T3, and the second, in the form [8]:

$$\Omega_F = -0.5 \ \text{Atan} \ [\ T3 / (Tv - Th) \ ] \qquad (1)$$

This has been verified over ocean with data from Aquarius [4] and recently with SMAP [6]. Fig. 1 is an example of data from SMAP [6]. The figure shows the
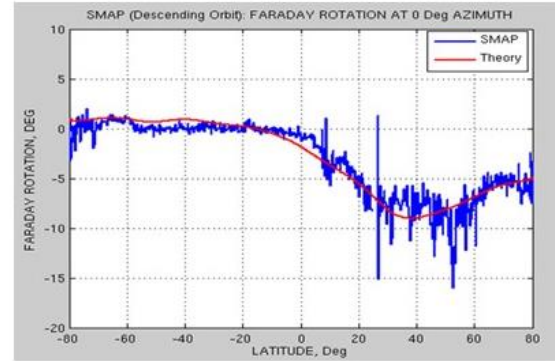

Figure 1. Example of retrieved Faraday rotation using Eqn 1 from SMAP. Top: SMAP ground track. Bottom: Retrieved Faraday rotation (blue) and theory (red). The descending (right) half-orbit is shown.

Faraday rotation angle (blue) retrieved using Eqn 1 at a fixed scan position (forward looking along the ground track). The red curve is the prediction of theory obtained using the TEC from IGS [http://www.igs.org/products/] and the Earth magnetic field [2, 3]. This data is for the descending portion of an orbit that starts over Asia (positive latitude) and continues over the Indian ocean (negative latitude). The agreement of measurement and theory is good over ocean (negative latitude), but over land there is significant noise. This is due to a combination of effects including inhomogeneity of the scene and dense vegetation which cause large spurious values in the ratio in Eqn 1 [3, 5].

3. PROPOSED APPROACH

The Faraday rotation angle depends on the orientation of the propagation path with respect to the local Earth magnetic field and the TEC along the path. To a reasonable first approximation this relationship can be written [2]:

$$\Omega_F \approx 6950 \, B \cos(\Theta_B) \sec(\theta_P) \, VTEC \qquad (2)$$

where B is the magnitude of the Earth magnetic field, Θ_B is the angle the propagation path makes with the magnetic field, θ_P is the angle the propagation path makes with respect to the vertical, and VTEC is the total electron content from surface to spacecraft. These parameters are evaluated at the point where the ray path passes through an altitude of 400 km.

The approach here is to use the value of Ω_F determined from Eqn 1 in Eqn 2 to compute a value of TEC. This will be done for each of the synthesized SMOS radiometer beams (i.e. one for each pixel on the surface). To reduce noise, values for several snap shots on each side of the reference snap shot will be used as indicated in Figure 2. In the work done to date 15 snap shots before and 15 after the reference were used. To further reduce noise, these values of TEC are averaged to produce a single value for each SMOS "snap shot".

4. VALIDATION

In order to test this approach, the TEC were compared with values retrieved using Aquarius measurements. This was done using data where SMOS and Aquarius crossed at almost the same time (within one hour).
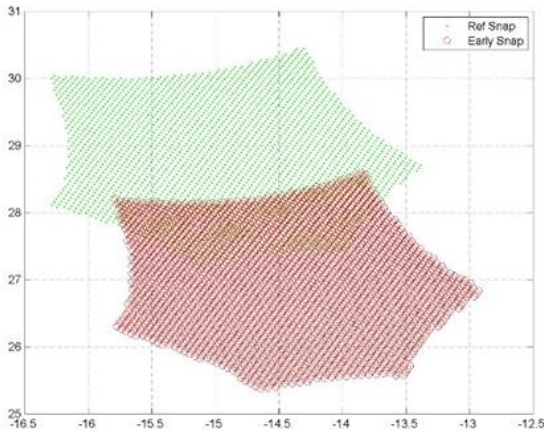

Figure 2. The reference pixel (green) and one of +/- 15 adjacent pixels (red).

Fig. 3 shows an example. The figure on the top is the SMOS reference snap shot with the values of TEC at each pixel displayed in color. The image the bottom shows the SMOS field-of-view with the Aquarius ground track and boresight from the three beams superimposed. (The ground track is line on the left.)
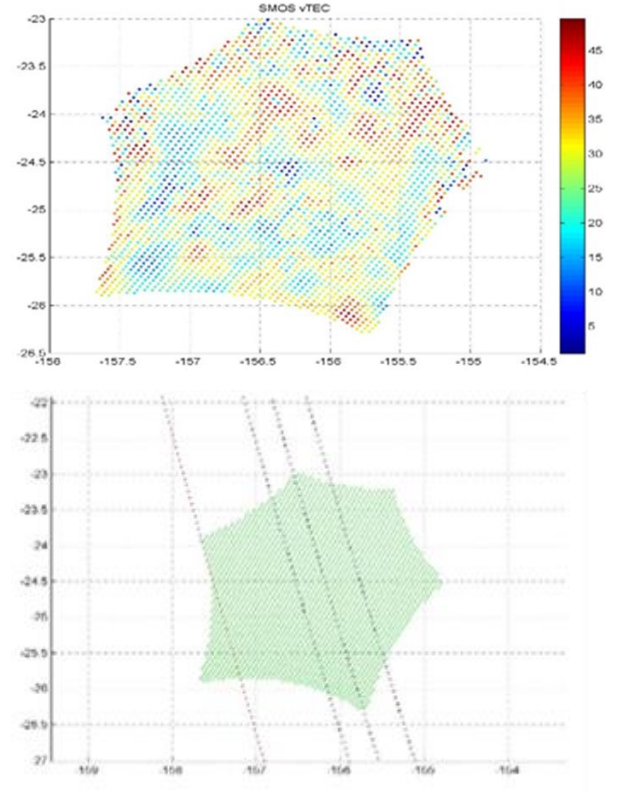

Figure 3. Top: The SMOS snap shot with the average values of TEC at each pixel shown in color. Bottom: The SMOS snap shot with the tracks of the three Aquarius beams superimposed (and also the Aquarius ground track).

5. RESULTS

To date 18 intersections of SMOS and Aquarius have been identified for processing. Of these, all but three gave reasonable agreement of the retrieved TEC. One was discarded as being close to land in area suspected of being subject to RFI. The other two are in the same location and are as yet unexplained. The remaining intersections produced values of TEC with an average difference of less than 3 TEC units.

6. SUMMARY

This work is part of a study to determine whether using the average TEC to correct for Faraday rotation may provide a more reliable correction for the polarization rotation than using individual noisy (i.e. irregular) values. Initial results suggest that the TEC retrieved from SMOS are reasonable.

7. REFERENCES

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